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Survey Guidelines for Soil and Water Conservation Projects

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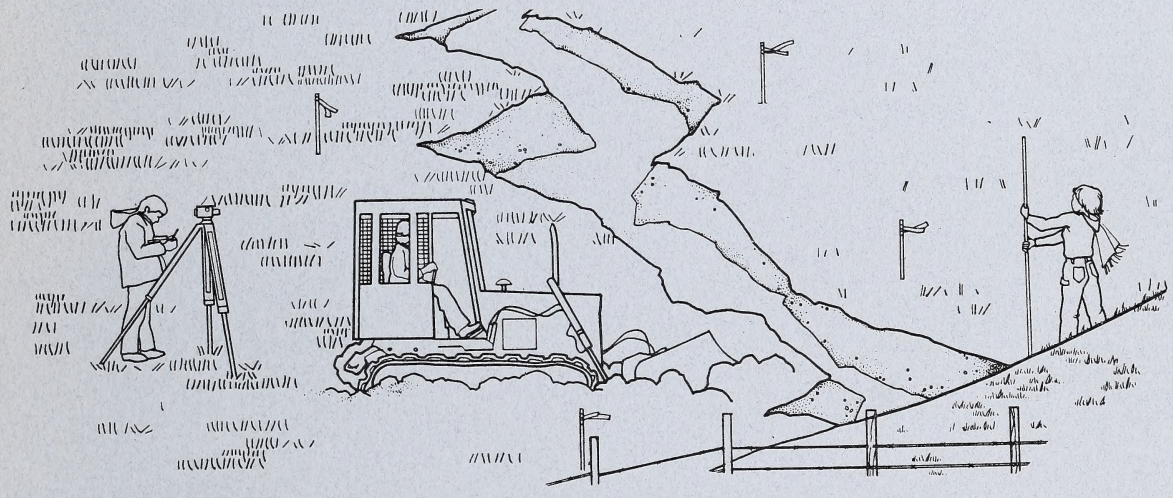

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AGRICULTURE, FOOD AND
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Preface

These guidelines have been prepared to help experienced surveyors become familiar with the particular engineering survey requirements for the development of farm scale soil and water conservation projects. It is not intended as a primer on the fine points of conducting a survey or operating a survey instrument.

Soil and water conservation projects involve the management of water for improved soil moisture for crop production, domestic and stock water supply, soil degradation control, and the maintenance of water quality. The survey requirements for these different types of projects vary, but all projects require accurate, detailed measurements and field information for successful planning, design and development.

Acknowledgements

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Survey Guidelines for
Soil and Water Conservation Projects

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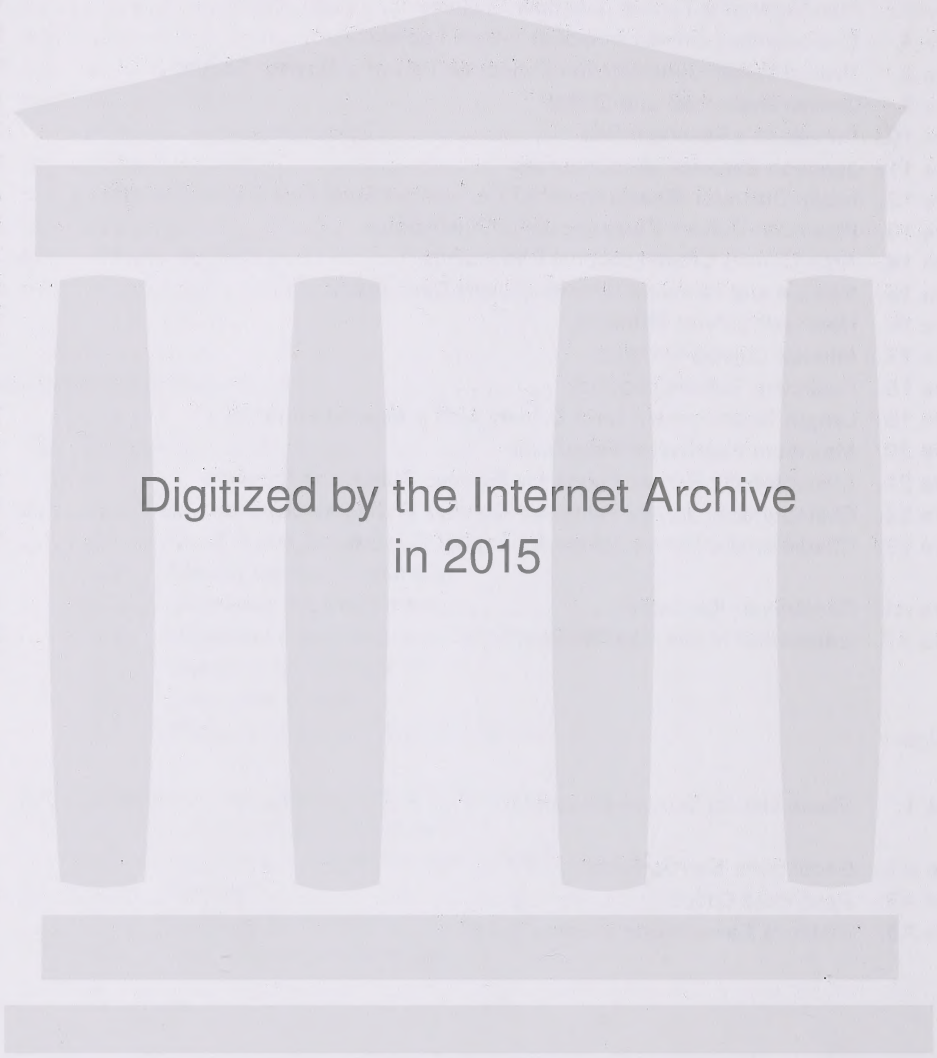

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1.0 Getting Started

Several important steps should be taken before doing an engineering survey for a soil and water conservation project.

1.1 Consultation

Consult the farm manager as well as municipal and provincial agricultural staff in the local area prior to scheduling the survey. Municipal and provincial staff need to know what is happening within their jurisdiction, and farm managers need to meet with the survey crew at the project site to describe the problem to them.

1.2 File Review

Prior to going to the project site, review all available information on the proposed project. This information should be kept in a project working file. Working files should include all relevant preliminary information such as the following:

a. **Completed Application:** The application should provide information on the project's land location, the owner's name and address, the problem and the proposed solution.

b. **Government Department Referral Response:** A request for input on the project should be sent to provincial government departments that may have an interest in the project. This could include departments involved in water management, rural land use and wildlife protection. A record of their response should be in the file so any concerns can be addressed at the initial stages of the project.

c. **Inspection Report:** The pre-survey inspection report should include a concise description of the problem and the proposed solution as well as a sketch of the project site and the proposed survey alignment. The location and description of culverts and other pertinent features, such as inlet and outlet structures requirements, land use in the area, approximate contributing watershed area and expected flow rates, should also be included in the report and the preliminary sketch. Any special instructions for the surveyor/designer should also be noted in the report.

d. **Topographic Maps:** These maps show the general characteristics of the project site and the areas upstream and downstream of the site. Features

for which survey information is required should be clearly identified and highlighted.

e. **Aerial Photographs:** The watershed may have been sketched on small scale airphotos (1:15,000 or 1:30,000). A large scale airphoto blow-up (1:5000) of the project site should also be in the file. The blow-up should have an attached mylar overlay showing details of the survey alignment and pertinent features.

f. **Municipal Maps:** Municipal maps show the legal land divisions and ownerships.

g. **Soil Map and Information Sheet:** Description of the soil type is important for erodibility and drainage considerations.

h. **Correspondence:** This may include memos, telephone notes and letters concerning the project.

Familiarize yourself with the documentation in the working file. If all the above information is in the file then the instructions for the survey should be straightforward.

1.3 Site Reconnaissance

To locate the project site, take a provincial road map and a municipal map. On site, check over the application form with the farm manager to ensure it is complete and accurate. Ask him for any information he can provide concerning the history of the project. Ask for details or ideas regarding the frequency, rate, depth and volume of runoff, and note these details in the survey book. This will assist with the survey and the design process.

If possible, drive or walk through the project area with the farm manager. Include any downstream and upstream areas which may be of concern. Correlate what you see with information from the farm manager and the working file, and make changes as necessary. Check the watershed area, culvert locations and sizes, high water marks and channel dimensions, and then proceed with the survey.

2.0 General Requirements for Level Surveys

Some general survey requirements apply to all soil and water conservation projects. These general requirements should be applied in addition to the specific requirements for the various types of surveys described in Chapters 3, 4, 5 and 6.

a. Equipment and Supplies

Before you go to the project site, use the *Check List for Survey Equipment* (Table 1) to confirm that you are taking all the necessary equipment.

b. Stations

The standard station interval should be no longer than 50.0 m along all profile lines such as channel centrelines. Stations should be marked with flagged survey lath. Additional stations should be marked and surveyed where a significant change in elevation occurs along the route.

If stations are to be chained, they should be set in (staked) first for the entire project. If pacing or using a belt chain, the stations can be set in as the level survey progresses. Mark all the stations on the airphoto overlay in as much detail and as accurately as possible.

c. Cross-sections

Take cross-sections of all survey routes including natural and man-made watercourses. Cross-sections should be taken at intervals no greater than 300.0 m. Additional cross-sections of the survey route should be taken at every location where a significant change in the cross-section occurs. The information that a given cross-section is typical for a given survey length should be included in the survey notes (e.g. 0+150 X-SEC TYPICAL 0+000—0+300).

The minimum width required for a cross-section depends on the cross-section shape, but a minimum of 15.0 m is recommended. Cross-sections of defined channels should include shots at the deepest point and all grade breaks, including the toe and top of the channel banks. Rod readings should be recorded from the left bank to the right bank (left and right are determined by facing downstream).

Table 1. Check List for Survey Equipment

Geodimeter

- ☐ Geodimeter
- ☐ Data Collector
- ☐ Data Collector Manual
- ☐ Data Collector Bracket
- ☐ Data Collector Cable
- ☐ Thermometer
- ☐ Land Elevation
- ☐ Prism
- ☐ 2 Handle Batteries
- ☐ 1 External Battery
- ☐ Chargers
- ☐ Geodimeter Tripod
- ☐ Geodimeter Rod
- ☐ Geodimeter Set-up Sheet

Level

- ☐ Level
- ☐ Rod for Level
- ☐ Tripod for Level

General

- ☐ Chain
- ☐ Stakes
- ☐ Crayons
- ☐ Survey Book
- ☐ Flagging
- ☐ Hubs
- ☐ Municipal Map
- ☐ Topographic Map (NTS 1:50,000)
- ☐ Township Sheet
- ☐ 2 Walkie Talkies
- ☐ Project Working File
- ☐ ATV Keys
- ☐ Calculator
- ☐ Hatchet
- ☐ Shovel
- ☐ Pencils and Ruler
- ☐ Rain Jackets
- ☐ Rubber Boots

d. Change in Slope

Whenever an obvious change in slope occurs, the elevation and chainage of the point where the slope change occurs should be measured and noted in the survey book (e.g. GRADE BREAK AT 1 + 130).

e. Upstream and Downstream Features

Make sure the survey does not end before reaching a suitable outlet such as a well defined watercourse. Survey all features upstream from the project that will influence project stream flows.

f. Significant Features

- Benchmarks, landmarks and survey route alignments should be sketched on the airphoto mylar overlay. Include enough detail to allow the alignment to be located at a later date if the stakes are lost.
- The elevation of existing and high water level marks in ditches, structures and culverts should be surveyed. Note water mark locations in the field book.
- Indicate only approximate locations of buried utilities on field note sketches.

g. Surveyed Points

- Number all structures, culverts, bridges, etc. in the order they are surveyed.
- Designate profile lines by letters (e.g. "A", "B", "C", etc.) in the order they are surveyed. All profile lines are to begin at Station 0 + 000.

h. Circuit Tie-in

A level circuit tie-in should not be out more than 5 mm per level set-up, to a maximum of 50 mm. If the error is greater, rerun the circuit.

i. Level Set-ups

To minimize error, level set-ups should be centred as close as possible between turning points and benchmarks.

j. Turning Points and Benchmarks

Set turning points and benchmarks where they will not be disturbed by project construction. Mark the locations with lath and flagging to make them highly visible.

k. **Rod Readings**

- Plumb the survey rod when taking rod readings on benchmarks and turning points. For all other shots, make sure the rod is held in a vertical position. If necessary, use a rod level to ensure this.
- Use 100.000 m when assuming an elevation for a starting benchmark.
- Interpolate or estimate rod readings on benchmarks or turning points to the nearest mm.
- Take a check shot on the benchmark or turning point before moving the level if that set-up is not tied in to the level circuit.
- Take all intermediate foresights to the nearest cm (take 0.005 to next lower cm).

3.0 Survey for Erosion Control Projects

3.1 Natural Waterway Improvement

Natural waterways are surface drainage channels and previously constructed grassed waterways which periodically carry runoff from the contributing watershed. They usually have a well established grass cover (Figure 1). Typical flow rates are 1.0 to 3.0 m^3/s. Average width varies from 7.0 to 30.0 m.

Figure 1. Characteristic Survey Points for a Grassed Waterway

Survey Requirements

The elevations of the channel centreline and the lower bank should be surveyed at 50.0 m intervals. The minimum cross-section width should be 15.0 m. The lower bank elevations should be taken at 7.0 to 8.0 m from the centreline to provide sufficient information about the flow depth limitations for the future channel.

In most cases the survey centreline will follow the *channel thalweg* (the line defined by the deepest points in the channel). In the case of interceptor channels (see Section 3.3), the centreline refers to the proposed centreline of the future channel which must be laid out in the field by the surveyors.

3.2 Erosion Control Channels

Erosion control channels include constructed grassed or ungrassed channels in well established watercourses. Erosion is controlled in these channels by use of grade control and adequate channel dimensions. Typical flow rates are 0.40 to 1.50 m^3/s.

Survey Requirements

The elevations of the centreline and the lower bank at 50.0 m intervals should be surveyed (Figure 2). Scour holes occurring along the centreline should be surveyed by taking elevations of the upstream and downstream edges and the bottom. Additional information about the size and the shape should be given under 'NOTES' in the survey book (e.g. IRREGULAR - AVERAGE WIDTH 0.50 m). The minimum cross-section width should be 10.0 m. The lower bank elevations should be taken 5.0 to 6.0 m from the centreline to provide information about flow depth restrictions needed for the design of channel improvements. If scour holes occur to one side of the centreline, then the average length, width and depth should be entered in the survey notes.

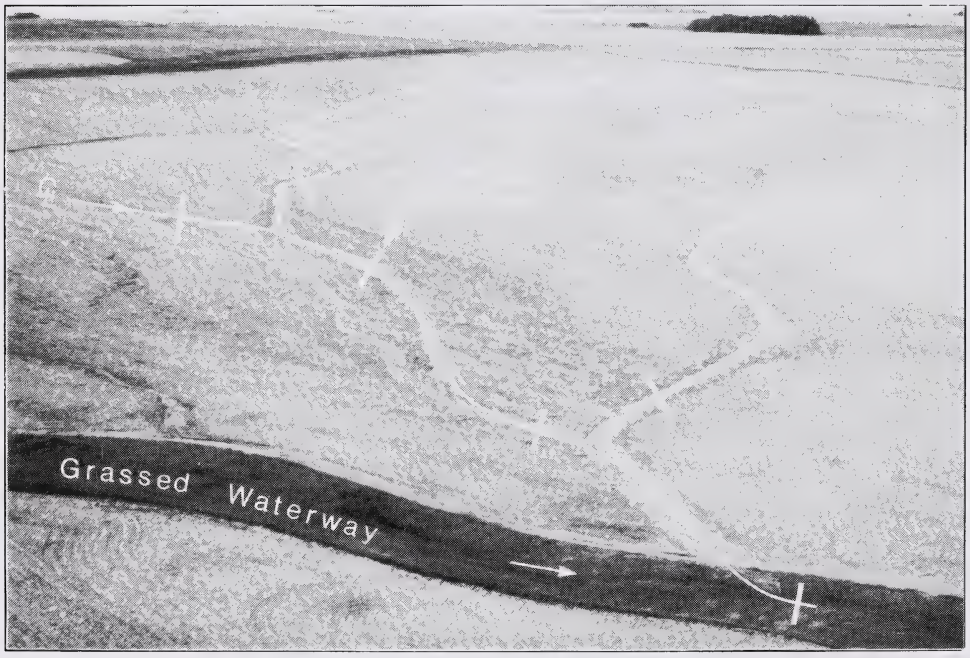


Figure 2. Characteristic Survey Points for Erosion Control Channels

3.3 Interceptor Channels

These channels intercept overland flow from adjacent watersheds (Figure 3). Typically erosion problems are evident on the downstream side of the interceptor channel location. In most cases interceptor channels are located along quarter section lines, and flow rates are usually between 0.30 to 1.00 m^3/s.

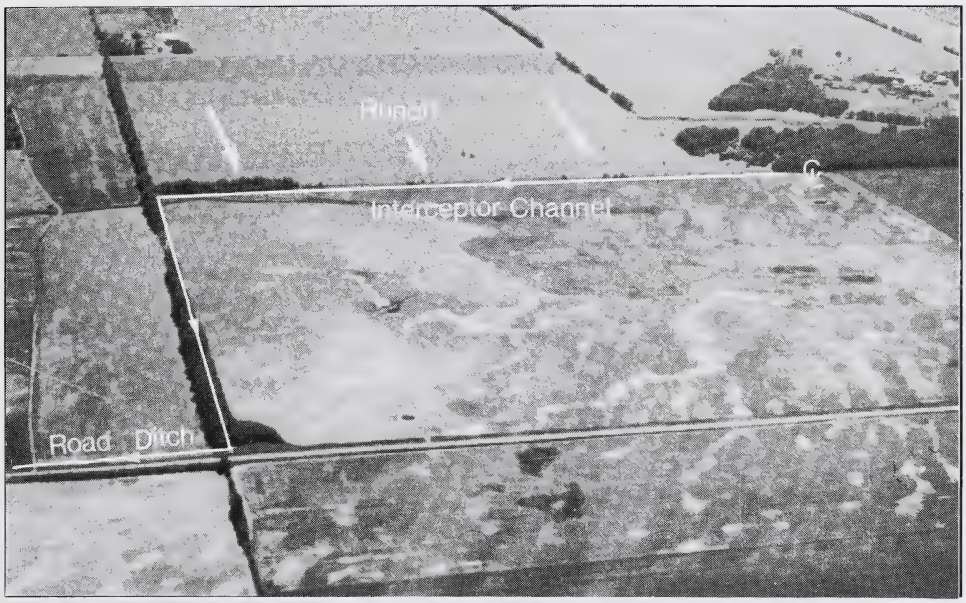


Figure 3. Interceptor Channel

Survey Requirements

The general alignment of the proposed interceptor channel will be shown in the inspection report. The survey crew must do the detailed alignment. The proposed location for an interceptor channel usually runs across the direction of natural overland water flow.

If an interceptor channel is to be located along a quarter section line (brush line, fence line, field boundary), the established centreline should be 4.0 to 5.0 m away from the boundary. The elevations of the centreline and both banks should be surveyed at 50.0 m intervals with one bank at the quarter section line and the other bank 5.0 to 6.0 m from the centreline. The minimum cross-section width should be 10.0 m and should include the bank at the quarter section line.

3.4 Gully Restoration

Gullies are an advanced stage of erosion occurring along natural waterways, channels and temporary watercourses. In the majority of cases, gully formation is very active with characteristic erosion at the upslope end of the gully (called *head cutting*). If not controlled, gullies can cause significant damage to farmland by washing away the soil and creating deep ravines. Gully erosion is caused by excessive water velocities and typically occurs on steep slopes.

Survey Requirements

The elevations of the gully centreline and the lower bank should be surveyed (Figure 4). It is important to indicate the stations at which the gully erosion starts and ends (e.g. 0+353 START OF GULLY, 0+378 END OF GULLY). A minimum of three typical cross-sections will be sufficient for most gullies provided the interval between cross-sections is less than 300.0 m. The cross-sections should include both banks with one additional shot taken 5.0 m from the bank top on each side of the gully.

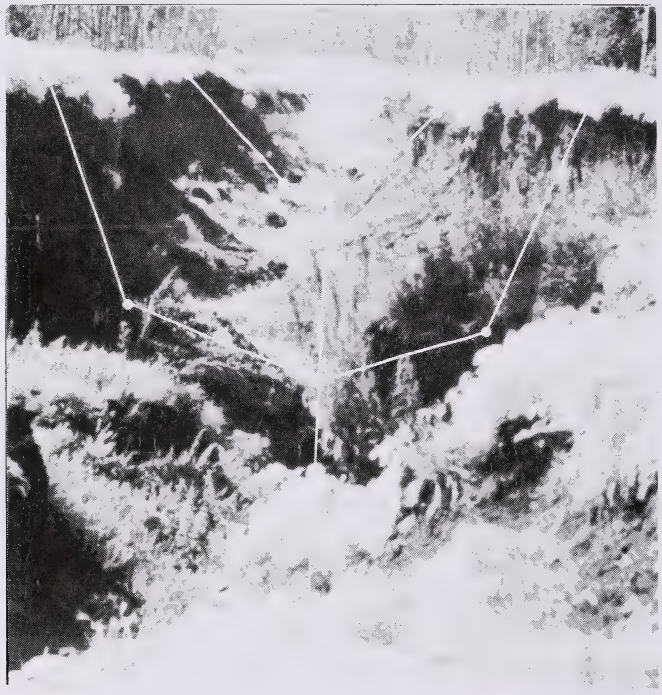


Figure 4. Characteristic Survey Points for Gully Restoration

3.5 Drop Structure Locations

Drop structures, such as drop inlets, chutes and pipe drops, are used where existing grades are too steep to control water erosion by open channels (Figure 5). Typical locations where drop structures are used include:

a. abrupt drops greater than 1.0 m deep in a channel (called *channel head cutting*); and

b. ravines where the channel drops from a field into an incised creek or river valley.

Figure 5. Characteristic Survey Points for Drop Structures

Survey Requirements

Extra care is required to obtain adequate and accurate survey information for drop structure locations. The designer's decision on the type of drop structure to be used is based primarily on site topography. Drop structure survey requirements, to a large extent, are up to the good judgement of the survey crew. A designer is looking for the following information from the survey notes:

a. **Location for the Inlet and Outlet:** The inlet is usually located at the upstream end of the gully or drop, preferably on undisturbed, mildly sloping or level ground. The outlet should be located at the bottom of the drop on mildly sloping or level ground suitable for installation of a stilling basin or other

energy dissipator. This might be an existing creek bed or ditch, or a level area preceding another drop. The survey must be extended until an adequate outlet is reached.

b. **Profile and Cross-section Elevations:** Existing profile elevations should be taken at 10.0 m intervals from 20.0 m upstream of the proposed inlet to 20.0 m below the proposed outlet. In addition, cross-sectional elevations are required at the inlet and outlet locations. The minimum width of these cross-sections should be 20.0 m. Additional cross-sections should be taken at alternate stations (i.e. 20.0 m intervals), and changes in cross-sectional shape should be noted.

3.5.1 Spillways for Drop Structures

To maintain the integrity of a drop structure during storms which exceed the structure's design capacity, it is necessary to construct an emergency spillway. In extreme flow events, erosion of the spillway can be expected and later repaired, while the drop structure will be unaffected. In most cases, the spillway is a chute or grassed waterway with an inlet upstream of the drop structure and an outlet downstream of the drop structure's outlet works. Figure 6 shows a plan view of a typical overflow spillway.

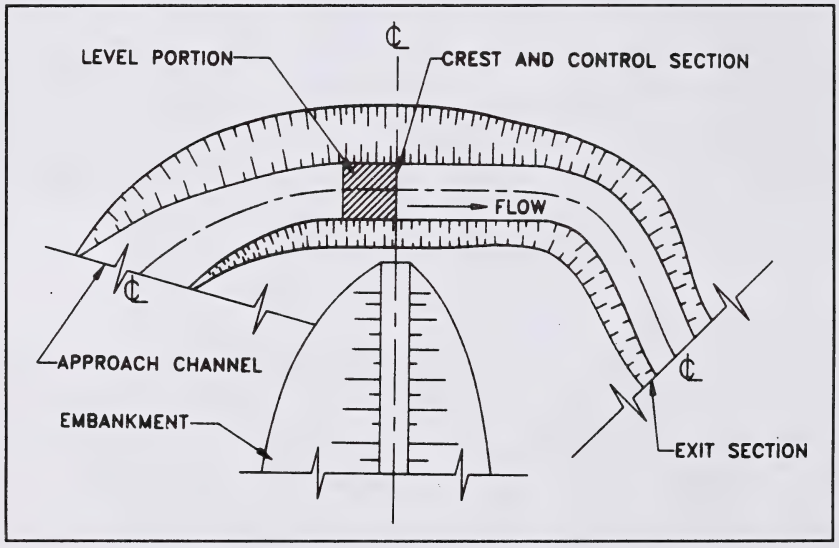


Figure 6. Plan View of a Typical Overflow Spillway

Survey Requirements

The survey crew needs only to locate and survey the alignment of the spillway route to the outlet. It is important to obtain elevations and cross-sections where the spillway leaves the main channel upstream of the structure and where it outlets. A minimum of three profile shots should be taken between these points unless the spillway is less than 50.0 m in length, in which case only one intermediate shot will be necessary. Elevations at grade breaks and cross-section changes should be surveyed.

3.6 Terraces

Terracing is a method of erosion control using broad channels parallel to the land contours. Terraces decrease the slope and reduce sheet and rill erosion, as well as supplying additional moisture to the soil by retaining runoff.

Survey Requirements

A number of surveys are required for the planning, design and construction of a terrace system:

a. **Topographic Mapping:** A topographic map of the proposed terrace system site is required for detailed planning and layout. The engineer's conceptual layout must be provided to minimize the amount of mapping survey required. The proposed layout will likely be shown on a sketch of the field or on a 1:5000 airphoto. With the alignment of the terraces in hand, the area 50.0 m on either side of each terrace should be mapped. Ideally this will be done using a total station survey instrument (for more information on total station survey refer to the Appendix). The contour interval required will depend on the terrain's overall slope. For hillsides with about 4% to 6% slope, a suitable contour interval would be 0.3 m; for steeper slopes, a greater contour interval could be selected.

b. **Terrace Alignment Profile:** Working with the prepared topographic map, the engineer will more precisely align the proposed terraces. From this plan the surveyor will mark the alignment of the terraces in the field and survey the terrace line to obtain the terrace profile.

c. **Construction Staking:** Based on the terrace profile, the engineer will design and set the grade line of the terrace. This design forms the basis for setting construction stakes in the field to guide the construction contractor. Stakes will show depths of cut or fill for the terrace.

d. **Construction Grade Control:** A surveyor must be on site during terrace construction because there is little room for imprecision. For a graded terrace there must not be any low spots that will allow ponding of water. Terraces with ponded water are extremely susceptible to failure.

3.7 Earth Dams and Dikes

Earth dams with water level control structures are sometimes used for temporary water storage.

Survey Requirements

The inspection report usually indicates the site for the dam. The survey at the site should include a cross-section between the two highest points. For earth dams, the upstream side slopes are usually 3:1 and the downstream side slopes 2:1, depending on the dam height. The top width for small earth dams is usually 3.0 m. An upstream cross-section should be taken at a distance three times the dam height plus half the dam's top width from the dam centreline (Figure 7). Similarly, a second cross-section should be taken at a distance twice the dam height plus half the dam's top width downstream from the dam centreline. It is also recommended to survey at least two cross-sections of the temporarily flooded area to determine the reservoir's storage capacity. In addition, one cross-section should be taken every 10.0 m for 50.0 m downstream of the dam location to indicate outlet conditions.

3.7.1 Dam Spillways

Like a drop structure, a dam requires a spillway to maintain the dam's integrity during storms which exceed its design capacity. It is preferable to divert runoff around the dam; if this is not possible, the spillway can be placed on the dam itself. The surveyor should note this situation in the survey book (i.e. "NO ALTERNATE SPILLWAY ROUTE AVAILABLE"). In these cases, the downstream slope of the dam embankment may be reduced to as little as 10:1, depending on the dam height, to allow for spillway construction. Cross-sections should be taken at 10.0 m intervals downstream from the dam centreline for at least 50.0 m plus 10 times the expected dam height.

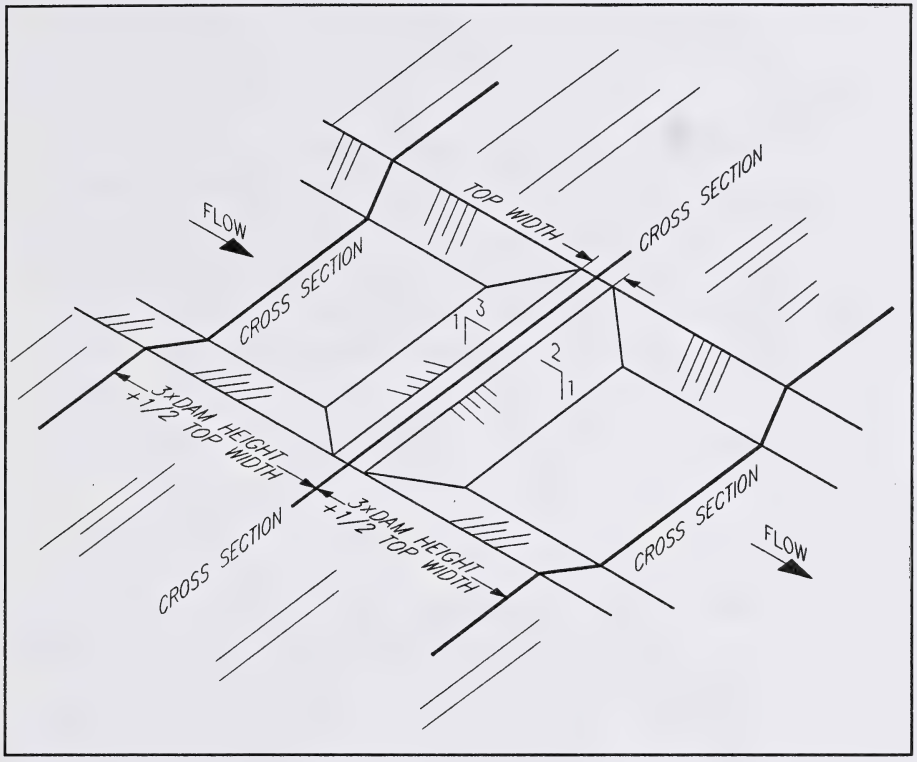


Figure 7. Characteristic Survey Points at a Dam Location

4.0 Survey for Water Management Projects

4.1 General

Water management projects commonly involve survey of relatively flat or gently rolling topography. Inspection reports may not always show the best alignment for the proposed channels; surveying is often needed to locate the best alignment. When the line is located it must be clearly marked on the airphoto overlay and on the ground using as many landmarks as possible which can be relocated during construction. The use of permanent landmarks and accurate sketches is critical because survey stakes and temporary marks are usually lost during construction. Without benchmarks and landmarks it will be impossible to do grade checks during construction.

4.2 On-Farm Channel Improvement

Channel improvement projects involve improving or restoring farm waterways and channels to reclaim waterlogged or flooded areas. Commonly occurring flow rates are 0.40 to 1.50 m^3/s.

Survey Requirements

The elevations of the centreline and the lower bank should be surveyed at 50.0 m intervals. Cross-section widths should be at least 10.0 m. Lower bank elevations should be taken 5.0 to 6.0 m from the centreline.

4.3 Field Depression Drainage

Field depressions, or temporary potholes, are depressions which fill with water during snow melt and heavy rainfall events and slowly drain by infiltration into the soil. Persistence of water in depressions over prolonged periods of time can delay farming operations, reduce crop productivity and, in some cases, remove land from production. Depressional drainage usually involves the design of a network of shallow ditches connecting the depressions and draining excess water. Due to the relatively small capacity of the average depression, commonly occurring flow rates are 0.15 to 0.50 m^3/s.

Survey Requirements

Typically field drainage channels have 3.0 m bottom widths and 10:1 side slopes, and are designed to be farmed through. The channel centreline and the lower bank should be surveyed at 50.0 m intervals. The elevations at the deepest point (usually the centre of the depression) and both edges along the centreline should be taken. This information is needed for calculation of the depression's capacity. Cross-sections of the depressions are not required. Ridges along the centreline between depressions should be surveyed. Cross-section widths should be at least 10.0 m. Lower bank elevations should be taken 6.0 to 7.0 m from the centreline.

4.4 Water Consolidation

During runoff events, potholes and depressional areas are filled by water. Depending on the soil permeability and evaporation rates, water may persist in these areas for prolonged periods, sometimes permanently. Water consolidation involves moving water from several potholes/depressions and storing it in a larger water body to improve field conditions and provide a long-term water reservoir (Figure 8). The stored water may be used for stock watering, supplemental irrigation or domestic and recreational uses.

A typical channel for water consolidation has a 3.0 m bottom width and 10:1 side slopes, and is designed to be farmed through. Commonly occurring flow rates are 0.30 to 1.00 m^3/s.

Survey Requirements

Elevations of the ditch centreline and the lower bank should be surveyed at 50.0 m intervals. Also the elevations of the centre of each pothole/depressional area and both edges along the centreline should be taken. Cross-sections should be included for potholes with an irregular shape. The surveyor's judgement and experience can be used to determine the number of cross-sections needed. In most cases three cross-sections are sufficient to supply the information for capacity calculations. The elevations of ridges between potholes or low spots should be taken to provide reliable information for the required earthwork volume and the range of cuts involved during construction. Cross-section widths should be at least 10.0 m. Lower bank elevations should be taken at 6.0 to 7.0 m from the centreline.

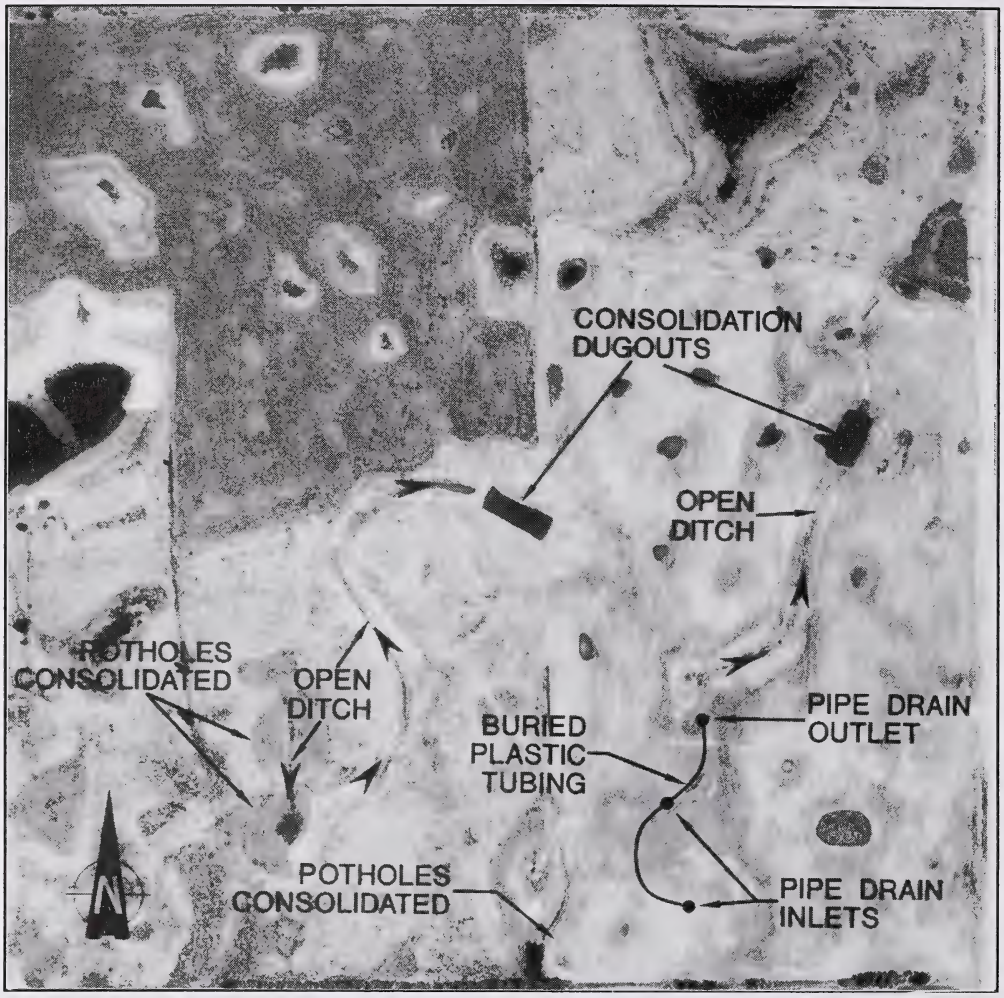


Figure 8. Typical Water Consolidation Project on Part of a Quarter Section

4.5 Peatland Water Management

Peatland water management involves reclamation of saturated organic soils by controlling and fluctuating the water table by means of field ditches and/or subsurface drainage.

Survey Requirements

In most cases peatlands are relatively flat, and therefore surveying of typical cross-sections is not required. The elevations of the centreline should be surveyed at

100.0 m intervals. For steep and narrow peatlands, the lower bank elevation at each interval should be taken at 6.0 to 7.0 m from the centreline.

4.6 Subsurface Random Pipe Drainage

In some cases open channel construction is not technically and/or economically feasible due to the excessive volume of earthwork involved. An economical solution involves subsurface plastic tubing with Jensen Drain Inlets (Figure 9). This kind of drainage is used primarily to drain isolated potholes separated by high ridges. However in some cases when slopes are steep and flow rates are low (up to 0.20 m^3/s), using a single buried pipeline becomes an economical solution for controlling water erosion.

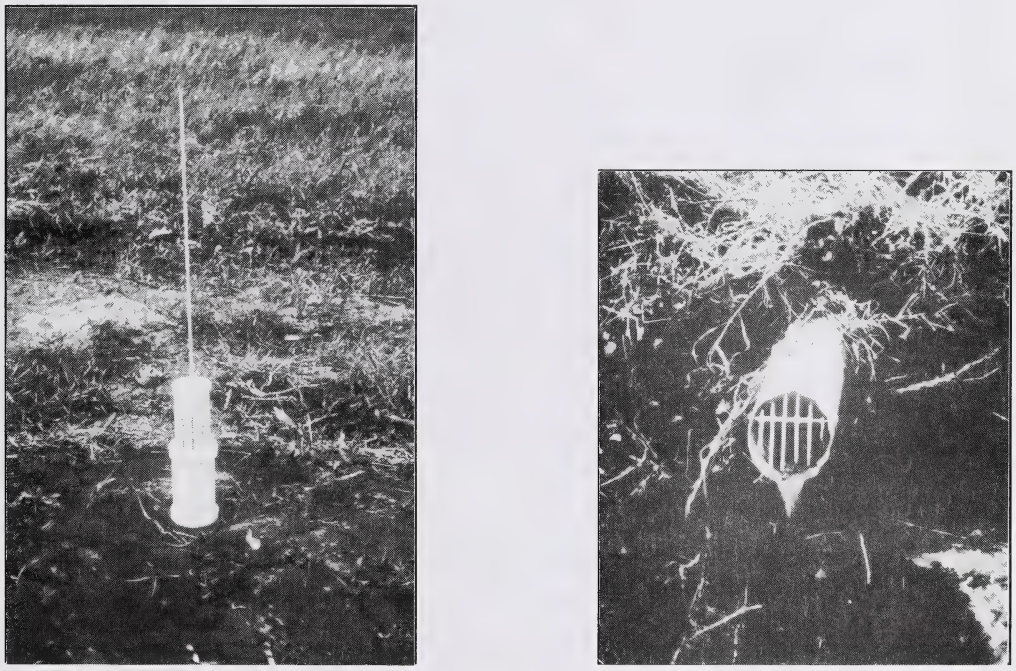


Figure 9. Jensen Drain Inlet (left) and Outlet

Survey Requirements

Only the elevations of the centreline should be surveyed. It is recommended to use a 10.0 m interval for slopes greater than 10%, a 20.0 m interval for slopes between 5% and 10%, and a 50.0 m interval for slopes less than 5%.

5.0 Survey of Common Features for Conservation Projects

The most commonly used structures in soil and water conservation projects include dugouts, reservoirs, roadside ditches and junctions as well as supplementary inlet/outlet structures. The survey requirements for these structures to meet minimum design standards are given below.

5.1 Dugouts

Dugouts provide an on-farm water supply for agricultural or domestic use. In addition, many dugouts play a very important role in attenuating the flow rates along the natural watercourses. They can also be used as outlet basins for small watersheds with low runoff volumes.

Survey Requirements

A 60 m x 60 m grid survey will usually be sufficient for most dugouts; however the approximate required dugout size should be indicated in the inspection report or later by the designer. Intervals of 10.0 m are recommended between stations for the grid survey. The size and the shape of the dugout should be noted in the survey book (e.g. RECTANGULAR DUGOUT 20 m x 30 m). If a dugout is located at the centreline of the ditch/watercourse, the elevations of the inlet and outlet structures and the lower dugout bank should be surveyed. Dugout locations are usually offset from the main watercourses, in accordance with Prairie Farm Rehabilitation Administration (PRFA) standards and guidelines for dugout design.

5.2 Reservoirs

Reservoirs are natural depressions used for water storage. They can be used to decrease the peak flow rates along natural watercourses and may also be used for livestock watering, supplemental irrigation and domestic use. Almost any kind of natural depression can be used as a reservoir.

Survey Requirements

One method is to survey the entire depression designated to become a temporary reservoir. A grid survey can be done using 10.0 m intervals for slopes greater than 5% or 20.0 m intervals for slopes up to 5%. However this method is time consuming and inconvenient.

A quicker technique is to establish the centreline in the middle of a depression and take perpendicular cross-sections at 10.0 m or 20.0 m intervals, depending on the slope. If the established centreline changes directions, every change should be surveyed by measurement of horizontal angles with reference to North as 0°. This method is particularly useful for long, narrow and meandering reservoirs.

The method involves the following steps, as illustrated in Figure 10:

a. Set up the instrument and define North by using a compass and ranging pole.

b. Adjust the horizontal angle reading to 0°.

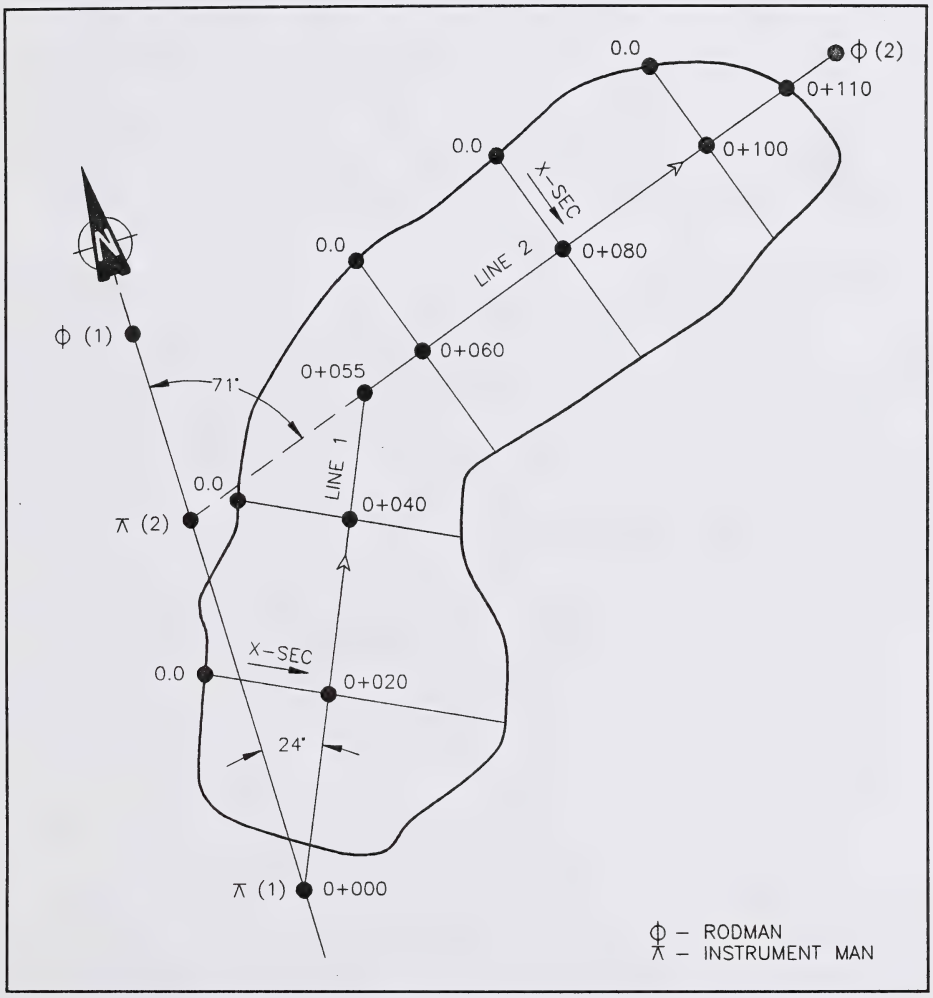


Figure 10. Survey of a Reservoir Site

c. Find the second instrument set-up and mark it.
d. Move the ranging pole to location 2 and establish line 2.
e. Establish line 1 declination from North.
f. Find the intersection of line 1 and 2 and mark it.
g. Stake out both lines at required intervals and survey cross-sections perpendicular to each line.

5.3 Roadside Ditches

Roads and roadside ditches are under provincial or municipal jurisdiction; therefore ditch improvement or reconstruction will require approval of the local authority and/or provincial department. Designers will avoid work in roadside ditches if possible. However, if these ditches are part of the project, a proper survey is necessary to obtain information about ditch capacity, grade and side slopes.

Survey Requirements

The elevations of the centreline and the lower bank should be surveyed at a 50.0 m interval. Cross-sections should extend from the road centreline to the edge of the field. In most cases, 5.0 to 6.0 m from the roadside ditch centreline will suffice. Road shoulders should be included as part of the cross-sections.

5.4 Junctions Between Channels

Survey Requirements

Junctions should be staked with an enclosed angle of 20° to 60° between ditch centrelines looking downstream (Figure 11). This type of junction will ensure smooth outflow from a secondary channel into the main channel and will also prevent junction erosion. Junctions at quarter section lines where channels join at 90° do not require staking.

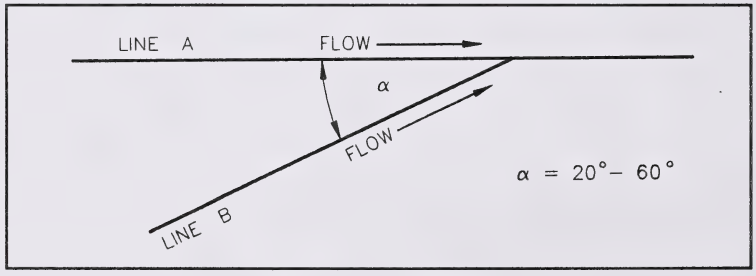


Figure 11. Junction Between Watercourses

5.5 Inlet/Outlet Structures

An *inlet* is the means by which water flows into the project site. It could be a culvert, channel, wetland, pond or undefined watercourse. An *outlet* is a well defined watercourse with sufficient capacity to receive flow from the project. Typical examples of outlets are sloughs, roadside ditches, natural creeks and rivers. Termination of a survey at a neighbouring landowner's property line is ***not*** adequate unless a well defined watercourse, as described above, is located at this property line.

Survey Requirements

A full description of the existing inlet/outlet conditions is always necessary. This should include features such as ponding water, erosion holes, washouts, debris accumulation, siltation, bank use and upstream use. For projects which do not have well defined outlets, the survey of the centreline and typical cross-sections should be extended for at least 50.0 m from the point where the original survey ends. This information is important to the designer when dealing with eventual outlet restrictions.

6.0 Survey of Culverts[1]

A complete survey of the culverts in and around the project site is very important in establishing the release of runoff to and from the project. Culverts can act to "choke" the flow from a watershed or to divert water into a project. In most cases a list of culverts is included in the inspection and pre-survey reports. The surveyor must make sure that the list is complete. Natural watercourses entering the project site should be checked where they cross roads. Airphotos should be reviewed and the roads around the project site should be checked.

The parameters which determine the hydraulic characteristics of culverts are length, diameter, shape, slope, type of entrance, headwater and tailwater depths, and material properties of the culvert. If properly measured, these parameters will allow a reasonable estimate of culvert capacity.

6.1 Cross-sectional Shape

Culverts are available in many different shapes. The most common shapes are round, arch, pipe arch, square and ellipse. The culvert shape depends on flow and overhead clearance restrictions.

6.1.1 Round Culverts

Measuring the inside diameter of corrugated steel pipe culverts, as shown in Figure 12, is sufficient.

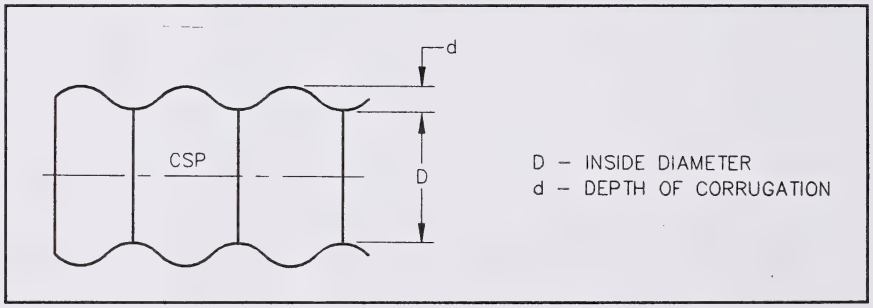


Figure 12. Inside Diameter Measurement of Corrugated Steel Pipe (CSP) Round Culverts

[1]For more detailed information about culverts, refer to *Handbook of Steel Drainage and Highway Construction Products — Canadian Edition*, published by American Iron and Steel Institute.

6.1.2 Wooden Culverts (Square)

Wooden culverts used to be very popular because they were more economical than steel pipes. They are gradually being replaced by corrugated steel pipes, but they are still common under railway embankments. They are usually square, therefore only the vertical or horizontal dimension needs to be measured.

6.1.3 Pipe-Arch Culverts

This culvert shape is used for low flows and limited overhead clearance. The span and rise, limited by the depth of corrugation, should be measured (Figure 13).

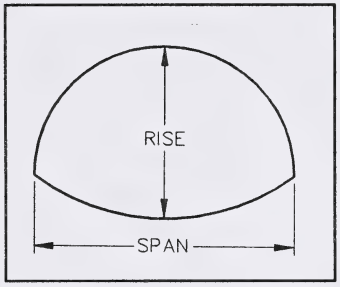


Figure 13. Pipe-Arch Culvert Cross-sectional Dimensions

6.1.4 Arch Culverts

Culverts with an arch shape are used where overhead clearance is limited and where it is desirable to maintain the natural stream bed. The span and rise, limited by the depth of corrugation, should be measured (Figure 14).

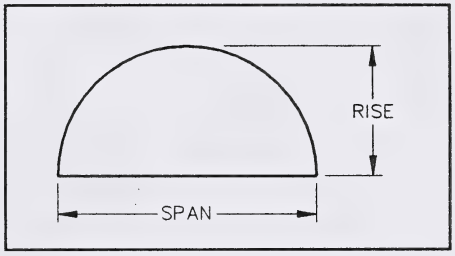


Figure 14. Arch Culvert Cross-sectional Dimensions

6.1.5 Ellipse Culverts

These shapes are used for high flows and limited overhead or side clearance. The vertical and horizontal dimensions should be measured (Figure 15).

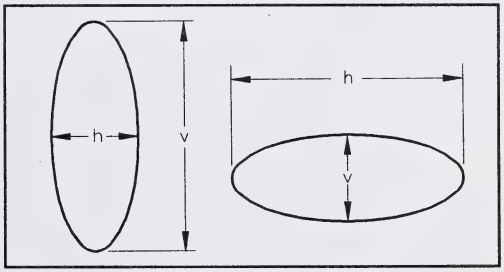


Figure 15. Vertical (v) and Horizontal (h) Ellipse Culvert Dimensions

6.2 Type of Culvert Entrance

There are three types of culvert entrance conditions, headwall (Figure 16), mitered (Figure 17), and projecting (Figure 18), for which the entrance coefficient K_e varies from 0.5 to 0.9. The type of entrance should be noted in the survey notebook.

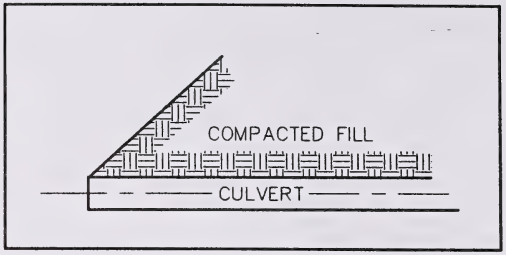


Figure 16. Headwall Culvert Entrance

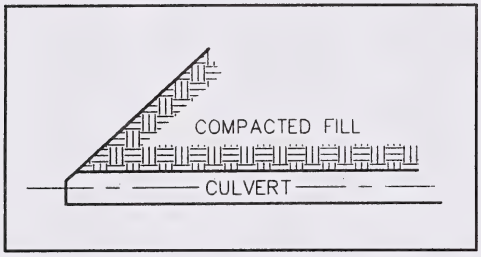


Figure 17. Mitered Culvert Entrance

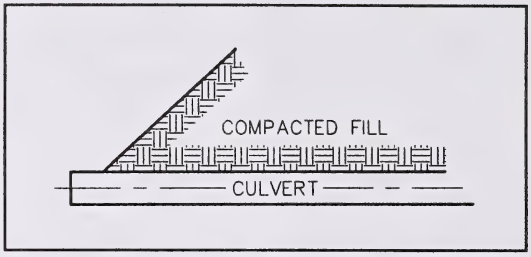


Figure 18. Projecting Culvert Entrance

6.3 Length of Culvert

The length of a culvert between the inlet and outlet inverts should be measured. This measurement is obvious for culverts with headwall or projecting entrances. For mitered entrances, the measurement should be done as shown in Figure 19. Measurement to the nearest 100.0 mm is sufficient.

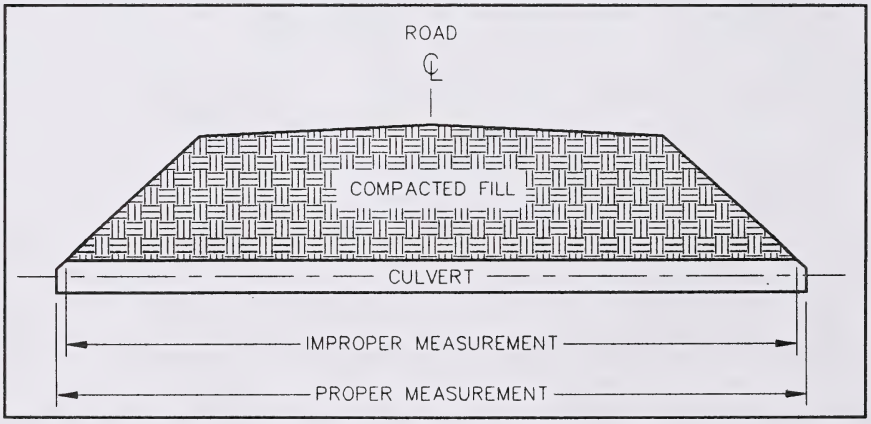


Figure 19. Length Measurement for a Culvert with a Mitered Entrance

6.4 Culvert Slope

The slope is defined as the difference in elevation between two points divided by the horizontal distance between them. As a general rule, the elevations of the inlet and outlet inverts of a culvert should be surveyed. The survey rod should be placed on top of a corrugation at the invert.

6.5 Culvert Capacity

Culvert capacity can be calculated analytically or determined from nomographs. Existing conditions at a culvert's inlet and outlet are the basis for calculations to determine the *head-discharge* relationship of the culvert. For *inlet control culverts*, the cross-sectional area of the pipe, the inlet configuration and the headwater depth are the main factors controlling culvert capacity. For *outlet control culverts*, the discharge capacity is limited by the outlet slope, roughness, the length of the pipe and the inlet configuration. The effective head causing flow of water through the outlet control culvert is the difference in elevation between the headpool (inlet) and the tailpool (outlet). The *headwater* is defined as the depth of water above the bottom of the pipe invert. High water marks on the channel banks usually indicate the depth of headwater. The headwater is limited by the height of the lower bank or the road embankment (Figure 20).

All these culvert characteristics are very important for a designer, and they should be properly and correctly recorded during surveying.

6.5.1 High Water Marks

Water marks may appear as stains on culvert embankments, bridge abutments or posts, or as vegetational debris or flattened vegetation along the channel banks. Where water marks are evident, there are usually marks at several levels. For survey purposes, the highest mark is the most important. High water marks can provide the designer with valuable information for determining peak flow rates. Whenever high water marks are found at a project site they should be surveyed. Cross-sections of the channel should be done at the high water mark location and at 20.0 m upstream and downstream of the mark.

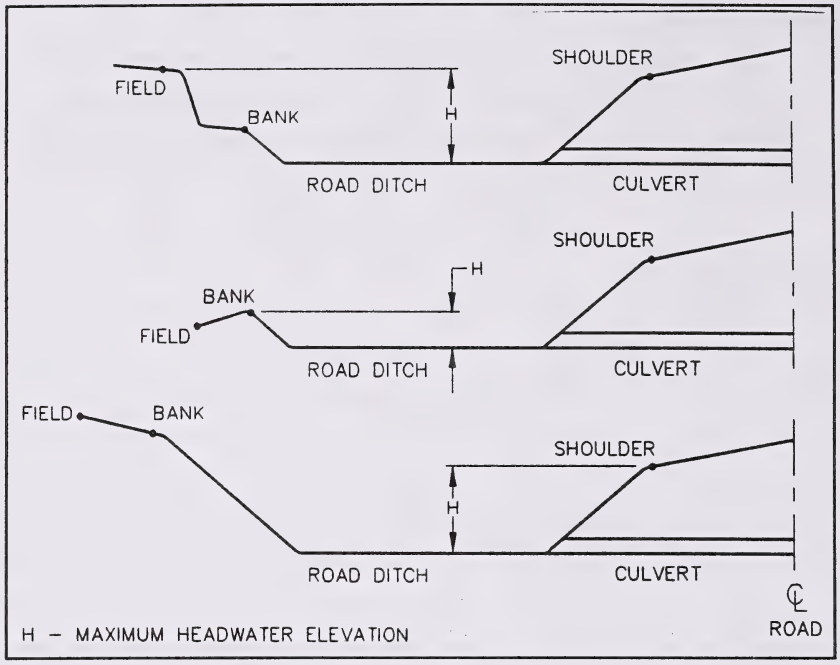


Figure 20. Maximum Headwater Elevations

6.6 Culvert Surveys

Characteristic points to be included in surveys beginning or ending with a culvert are shown in Figures 21 and 22. If the survey includes a culvert, the following information is required:

a. Culvert material (e.g. corrugated steel pipe, concrete pipe).
b. Culvert diameter and type: if the culvert is corrugated then the corrugation geometry should be noted (e.g. structural plate, helical, etc.)
c. Invert elevation of inlet and outlet.
d. Maximum headwater elevation.
e. High water marks at inlet and outlet, if available.
f. Shoulders and centreline of road elevations.
g. Channel profile for a distance of at least 50.0 m downstream of the culvert outlet including minimum of two channel cross-sections.

6.7 Lateral Culverts

Culverts are often located on tributaries to the main watercourse being surveyed. For example, this situation occurs when road ditches are used in

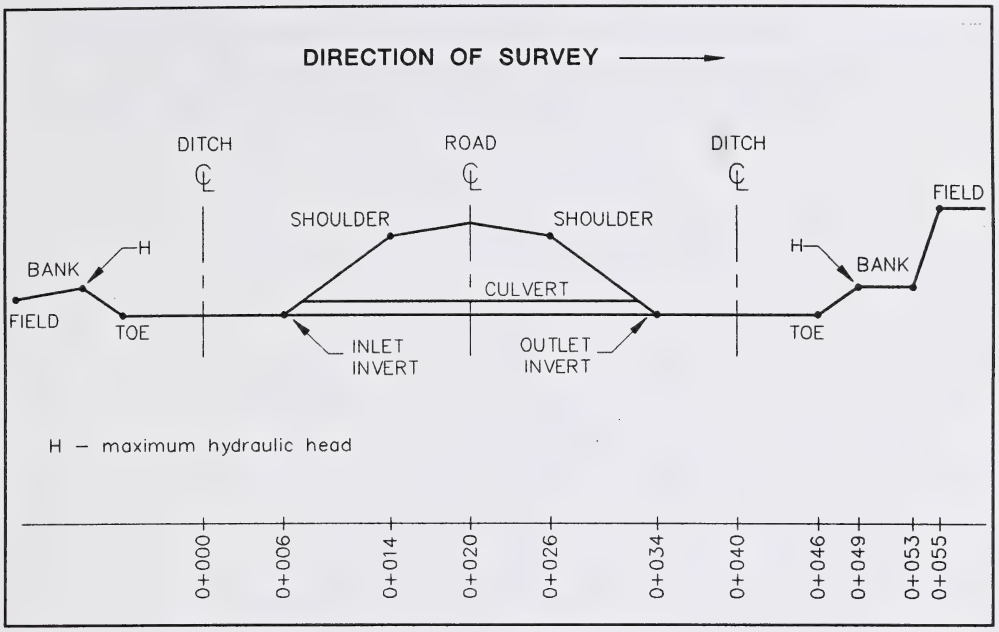


Figure 21. Characteristic Survey Points for Surveys Starting at Culverts

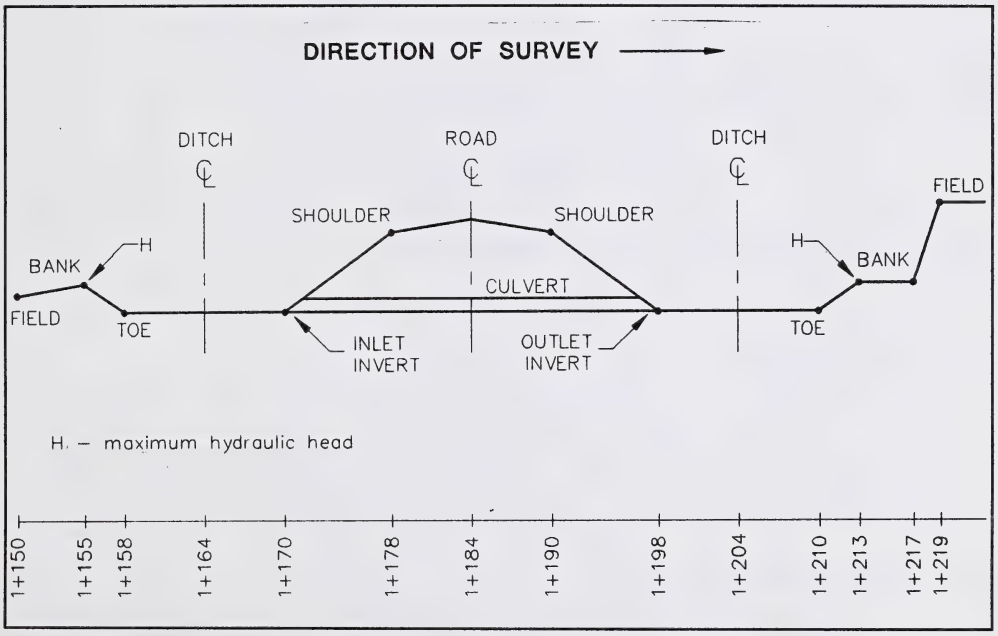


Figure 22. Characteristic Survey Points for Surveys Ending at Culverts

combination with a channel. In such cases, the stations where lateral culverts feed into the main ditch should be recorded in the survey book. Invert and maximum headwater and tailwater elevations should be surveyed (Figure 23). The size, length and type of culvert should be noted.

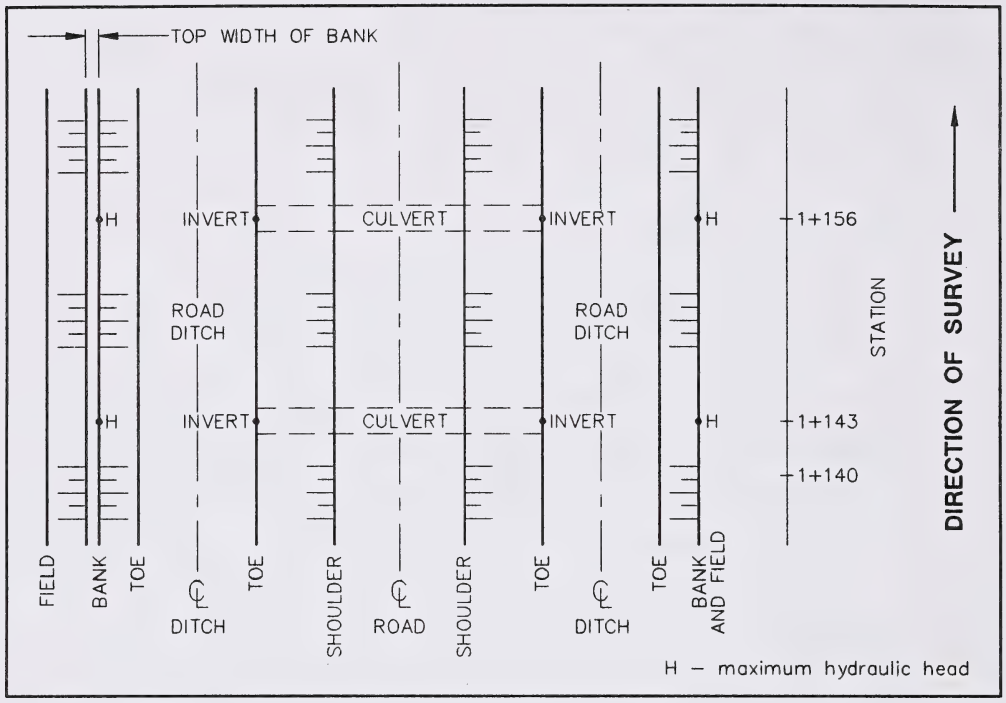


Figure 23. Characteristic Survey Points for Lateral Culverts

6.8 Silted Culverts

If a culvert is silted, taking the invert elevations at the level of siltation will not provide sufficient information to the designer. In such cases, the survey should also include the elevations of the top ends and the inside pipe diameter.

6.9 Culvert Condition

Culvert inlets and outlets may be damaged by snow removal and ditch maintenance operations. The top ends of projecting culverts are the most likely to be damaged. Culvert damage should be noted in the survey book (e.g. STA. 1 + 450 CSP 600 SLIGHTLY DAMAGED TOP AT INLET).

6.10 Erosion and Ponding

Any erosion or ponding problems at the inlet and outlet of a culvert should be noted in the survey book (e.g. STA. 1 + 730 CSP 600 EROSION HOLE AT THE INLET AND PONDING WATER AT THE OUTLET).

APPENDIX

Total Station Survey

Total Station Survey

This appendix outlines the basic procedures for surveying with a Geodimeter 400 and a TDS-500 Data Collector, and describes how the survey data can be used. Only a regular survey is described, and details are not provided on different specifications or objectives. To learn about all the functions available with the Geodimeter, read the Geodimeter and Data Collector manuals in conjunction with this chapter.

1.0 Preparing for Field Work

Take all necessary equipment and information into the field (refer to Table 1, *Check List for Survey Equipment*, on page 4). For total station survey, the following are particularly important:

a. The equipment must be handled with extreme care. The Data Collector has a special case to protect it from damage.

b. Be sure enough memory is available on the Data Collector to do the job.

c. All batteries (including the handle batteries and the large external battery on the Geodimeter, the Data Collector and the walkie talkies) must be fully charged. A good practice with these DC rechargeable batteries is to use them until they are almost fully discharged and then fully recharge them. This will ensure they do not lose their capacity to hold a new charge.

d. Determine the project's approximate land elevation in metres above mean sea level. This will be required to obtain a current pressure reading in the field.

e. If the survey requires a map with survey pins and azimuths of roads, a township sheet can be obtained through the provincial maps agency.

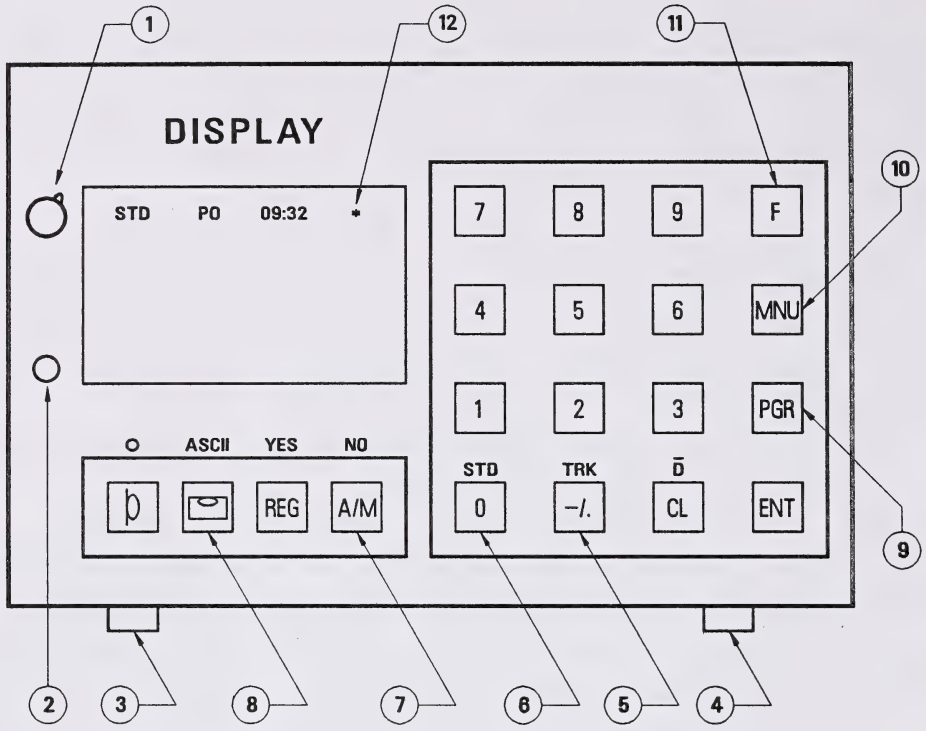
f. Review the Geodimeter manual to make sure you are familiar with the Geodimeter keyboard (Figure A1) and the key functions.

2.0 Field Work

2.1 Starting the Survey

a. Find a straight road or fenceline, and use this to get an accurate northing.

b. Select a high hill about 200 to 300 m from the road or fenceline, and use this location for the instrument set-up. Determine the best place to set up the instrument to get the most shots with the fewest set-ups. The more set-ups, the less accurate the survey will be.



1. ON/OFF SWITCH
2. AUTOMATIC ILLUMINATION SENSOR
3. CONTROL KNOB FOR ADJUSTING DISPLAY CONTRAST AND VIEWING ANGLE (ON UNDERSIDE OF PANEL)
4. SIGNAL VOLUME CONTROL
5. TRACKING MODE
6. STANDARD MODE
7. A/M MEASURE KEY
8. FINE LEVELING
9. PROGRAM KEY
10. MENU DISPLAY KEY
11. FUNCTION KEY
12. STAR INDICATES SIGNAL RECEIVED FROM REFLECTOR

Figure A1. Geodimeter Keyboard

c. Using three 2 inch x 2 inch wooden hubs, set Hub #1 and Hub #2 exactly the same distance away from the road or fenceline. Set Hub #3 in the ground where you want to set up the instrument. The hub to the left of the instrument is Hub #1 which has a northing of 5000, an easting of 5000 and an assumed elevation of 100.000 m. Hub #1 and #2 should be installed in an area which is unlikely to be disturbed.

2.2 Setting Up the Geodimeter

a. Set up the tripod over Hub #3 with the top plate level. Set the Geodimeter on the tripod and lightly tighten the screw into the Geodimeter. It is easier to level the instrument if the screw is not tight. If it is tightened too much it can cause the tripod plate to bend.

b. Use the level bubble located on the side of the Geodimeter to get the instrument approximately level. **Level the instrument first and then sight the optics to see if it is directly over the hub. If it is not, either shorten or lengthen one of the tripod legs. Never move the tripod with the Geodimeter attached.**

c. When the Geodimeter is level and over the hub, measure the height of the instrument (HI). Using the graduated tape measure supplied in the Geodimeter case, read the GDM 140 Red Line. Record this number to three decimal places in the Data Collector and write the measurement in a survey book.

d. Attach the Data Collector bracket, external battery and the three-way cable. The end plugs on the cable are marked to show the proper connections.

e. Take a temperature reading using the steel cased thermometer from the Geodimeter case. This thermometer should be installed on the side of the tripod and the temperature reading should be updated every hour.

f. Take a pressure reading by pointing the needle of the altimeter to the land elevation in metres you obtained in the office. Read opposite the zero mark for pressure in millibars (Mbar).

2.3 Initializing the Instrument

a. Turn the Geodimeter on. Using the coarse level display built into the Geodimeter, level the instrument so the bubbles are in the middle. When this is done, press the A/M key and wait. After the instrument beeps, turn the instrument 180° (or 200 gons) until the Geodimeter reads "Okay" and then press the A/M key again.

b. Enter the temperature and pressure readings into the Geodimeter. It will now ask for the "HA REF ANGLE". Enter the value the Geodimeter displays.

c. The Geodimeter now displays "HORIZONTAL ANGLE" and "VERTICAL ANGLE". Press the fine levelling key to make sure it is levelled exactly. Check to make sure the instrument is level during the survey.

d. Function #3 on the Geodimeter operates the HI, and Function #6 operates the height of the rod (HR). The HR can be changed as required during the survey, depending on topography. Keep in mind that the Data Collector will override the Geodimeter when different values are entered for the HI and HR.

2.4 Obtaining a Northing and Instrument Position

a. Using Hubs #1, #2 and #3 as BM #1, BM #2 and BM #3, respectively, use the triangle shown in Figure A2 to orient the instrument.

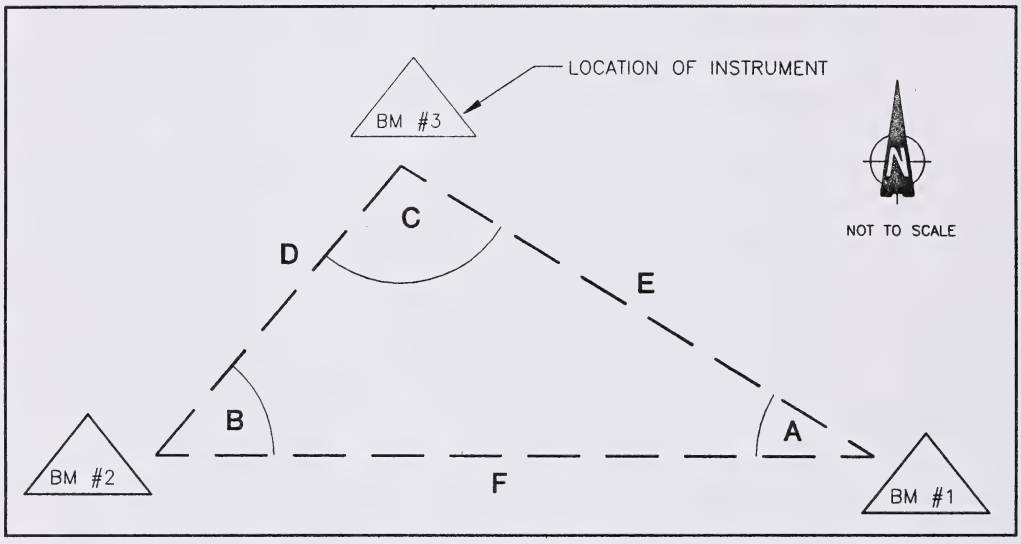


Figure A2. Orientation of the Geodimeter

b. When standing at Hub #3, the hub to the left is Hub #1 with an assumed elevation of 100.000 m. Angle C should be greater than 90° for a higher degree of accuracy for setting up.

c. Take a reading on BM #1 using the Geodimeter, not the Data Collector, to store the information. Sight on the two yellow triangles on the prism and press F (for function), 21 (for HA Ref Angle) and enter in 0 (zero). When the cross hairs are exactly on the prism on the rod, press A/M to take a shot.

Using the *Geodimeter Set-Up Form* (Table A1), precisely record the values for horizontal angle (HA), vertical angle (VA) and slope distance (SD). Press the ENT (enter) button on the Geodimeter to see other values including horizontal distance (HD), vertical distance (VD), northing, easting and elevation. Unlock the horizontal adjustment screws and turn the Geodimeter to Hub #2. Sight on the prism again and press A/M. Record all values using the *Geodimeter Set-Up Form*.

d. Calculating Coordinates:

i. A calculator, such as the HP28S, can be programmed to calculate Angle A based on the values recorded earlier:

- "E" is the horizontal distance from the Geodimeter to Hub #1.
- "D" is the horizontal distance from the Geodimeter to Hub #2.
- "C" is the horizontal angle from Hub #1 to Hub #2.

ii. Record Angle A on the previous set-up form. Press User, then select either SETW, SETE, SETS or SETN, depending on which direction the triangle is pointing. In the example in Figure A2, Hub #3 is pointing north (SETN). The calculator will give you coordinates for Hub #3. Enter these values into the Data Collector. From the main menu on the Data Collector, select A for open/edit a job, then D for edit coordinates. Enter the value for Hub #3 and store it as point #3 for easy reference. Hub #2 can also be calculated and stored at this time but it is not required.

2.5 Checking Benchmark #1

a. From the main menu on the Data Collector, select D (traverse/side shot). Enter in the occupy point (OC) as 3, the foresight point (FS) as 10 or 50, depending on the size of the survey, and the backsight point (BS) as 1. Enter the descriptor for this shot as "Check shot BM #1". If the HA REF is still 0 at BM #1, then a backsight shot is not required at this time. Enter into the Data Collector the HI that was recorded earlier and the HR that will be used to sight on the hubs.

b. Press A/M on the Geodimeter when sighted on the rod at BM #1. The HA REF should be 0 exactly when recording the shot and the VA should be the same as before. After pressing the A/M key, wait until the shot is taken, then press the F1 key on the Data Collector very slowly three times. Make sure the Data Collector beeps to indicate that the shot has been recorded.

Table A1. Geodimeter Set-Up Form

Project Name: _____ Date: _____

Project No.: _____ Land Elev.: _____

ABS: _____ Temp.: _____

Legal Descrip.: _____ Pressure: _____

Surveyor: _____ HI: _____

Rod Person: _____

BM #1 Description

HA: _____

VA: _____

SD: _____

HD: _____

VD: _____

Northing: _____

Easting: _____

Elevation: _____

BM #2 Description

HA: _____

VA: _____

SD: _____

HD: _____

VD: _____

Northing: _____

Easting: _____

Elevation: _____

BM #3 Description

Coordinates: _____

Elevation: _____

Angle A: _____

Sketch

c. Check to see if the shot is accurate enough. Using the "COGO" command in the Data Collector, enter in point #1 and the point number that was used to take the check shot. The difference should be within 4 cm total for horizontal and 1 cm for vertical. If the difference is greater than this, check your calculations or try another shot.

2.6 Descriptor Codes

Using descriptor codes helps you remember each shot. You can use up to 16 letters per description. The description of the shot should be entered before the shot is taken. To edit a description, select Edit Coordinates and then the point number under which the description was stored.

There are approximately 105 codes stored in the Data Collector (Table A2). Each code has its own number. This number should be the descriptor but do not press the enter key or the procedure will not work.

2.7 Measure Mode and Tracking Mode

The *measure mode* is used for shots which require a high degree of accuracy. **It should always be used for benchmark shots or any other required precise shot.**

The *tracking mode* is not as accurate as the measure mode, but it is precise enough for regular surveys. Topographic surveys can be carried out much faster with the tracking mode but this mode will run the batteries down much faster than the measure mode. After the Geodimeter has sighted on the triangles on the prism in tracking mode, make sure the rod is turned away from the line of the instrument or the signal will be distorted.

3.0 Computer Files, Calculations and Displays

3.1 Downloading to a Computer

To download the survey data you need a computer with TFR software and a cable to connect the Data Collector to the computer.

Several different files can be created using the TFR software, including:

a. **Raw Data File:** From the TFR main menu, choose "Transfer Raw Data - PC" and select file transfer "M" then "A" on the Data Collector. You have now created a raw data file. Store the file with the extension "RW5". **If the raw data file is deleted from the Data Collector, it cannot be uploaded again.**

Table A2. Descriptor Codes

1	TOPO
2	CL OF DITCH
3	CL OF WW
4	CL OF RD DITCH
5	TREE LINE
6	NS FL
7	EW FL
8	SHLD OF RD
9	INLET INVERT
10	OUTLET INVERT
11	CL OF RD
12	RT
13	LT
14	BERM
15	EDGE OF SLOUGH
16	EDGE OF WATER
17	POTHOLE
18	START OF EROSION
19	X-SEC
20	0+000A
21	0+050A
22	0+100A
23	0+150A
24	0+200A
25	0+250A
26	0+300A
27	0+350A
28	0+400A
29	0+450A
30	0+500A
31	0+550A
32	0+600A
33	0+650A
34	0+700A
35	0+750A
36	0+800A
37	0+850A
38	0+900A
39	0+950A
40	1+000A
41	1+050A
42	1+100A
43	1+150A
44	1+200A
45	1+250A
46	1+300A
47	1+350A
48	1+400A
49	1+450A
50	0+000B
51	0+050B
52	0+100B
53	0+150B
54	0+200B
55	0+250B
56	0+300B
57	0+350B
58	0+400B
59	0+450B
60	0+500B
61	0+550B
62	0+600B
63	0+650B
64	0+700B
65	0+750B
66	0+800B
67	0+850B
68	0+900B
69	0+950B
70	1+000B
71	CK HUB1
72	CK HUB2
73	CK HUB3
74	CK HUB4
75	CK HUB5
76	CK HUB6
77	CK HUB7
78	CK HUB8
79	CK HUB9
80	0+000C
81	0+050C
82	0+100C
83	0+150C
84	0+200C
85	0+250C
86	0+300C
87	0+350C
88	0+400C
89	0+450C
90	0+500C
91	0+550C
92	0+600C
93	0+650C
94	0+700C
95	0+750C
96	0+800C
97	0+850C
98	0+900C
99	0+950C
1000	0+1+000C
101	CK HUB
102	TOE OF DITCH
103	EROSION
104	1/4 LINE
105	PROPOSED DAM

b. **Contour File:** A contour file is used to delete incorrect shots. A workable format for this file is as follows:

```
          1         2         3         4         5         6
123456789012345678901234567890123456789012345678901234567890123456789012
PPPPPP    NNNN.NNNN EEEE.EEEE ZZZ.ZZZ   DDDDDDDDDDDDDDDD
```

This is the display on the computer. The top line stands for the tens, twenties, etc. The second line is the number of digits throughout the line. The last line has to be entered. The 6 P's stand for the point number; the 8 N's with a decimal stand for the northing; 8 E's with a decimal stand for the easting; 6 Z's with a decimal stand for the elevation; and the 16 D's stand for the description of the shot.

The above change in format is achieved by selecting "Change Convert File Format" and then selecting "Convert PC File - User Format File". **An easy way to delete or edit shots is to use the personal editor software (PE2).**

When jobs do not require descriptors or the point number, the following format can be used:

```
          1         2         3         4
12345678901234567890123456789012345678901234567890
NNNN.NNNNEEEE.EEEEZZZ.ZZZ
```

This format is for files that are all topographic (random) shots that do not need editing. You can create any type of file using this procedure, depending on the job specifications or the available software.

3.2 Uploading a Job to the Data Collector

If you have deleted a job and you need to access it again on the Data Collector, select "Transfer Coordinate File - TDS-500". When the display asks for a source file, enter "*.CR5" (or "a: *CR5"). This will show a list of files available in the specified directory. It is good practice to upload the entire file, not just a certain number of points. The program will ask you if you want to create a new raw data file. Answer "Yes". This will create a new raw data file when more surveying is done for the job.

3.3 Printing

Print out the raw data file for a project since these values will never change. When printing a raw data file, you will be asked if you want to print a cut sheet or not. A cut sheet is generally used to stake out coordinates with design grade elevations. A cut sheet is not required for most jobs.

For each job, every file should be printed and stored in the working file. Each file should be properly labelled with the project name, location and job number.

3.4 Distance Calculations

These calculations are mainly for jobs needing station to station distances. For surveying and designing resource conservation projects, it is a good idea to create this file. You need a general knowledge of Lotus 1-2-3 to perform the distance calculation procedure (Table A3). This file should be stored with the extension ".WK3" for consistency.

3.5 Data Display and Analysis

A total station survey easily provides more detail than a level survey. The data can be displayed and used in a wide variety of ways. Some examples are:

a. **Point Distribution Map**: For this, each surveyed point is plotted. The point number and descriptor are shown beside each point. The map shows points along waterways, dugouts, bush lines, fence lines, dam or dike locations, spillways, etc.

b. **Contour Map**: This map shows contour lines to the specified contour interval on the shots taken in the survey. It is especially helpful for calculating the storage capacity of proposed water storage areas. Low spots like sloughs or high spots like hills are easily seen on this map.

c. **Three-Dimensional Map**: This presents a three-dimensional view of the area surveyed. Although this map is hard to work with, it helps the viewer to visualize the landscape.

d. **Slope - Distance Calculations**: These calculations are valuable for configuring soil zones, flow paths or runoff volumes from a specified area.

Table A3. Distance Calculations in Lotus 1-2-3

The following procedure is used to calculate distances between points. For this example, "Smith" is the job name.

File
Import
Number
Escape (to clear line)
A:SMITH.PNT
Worksheet
Delete
A:G1...A:H1
(go into Box G2)
(@ SQRT (((B1-B2) ^2), ((C1-C2)^2)))
/ (to bring up main menu)
Copy
From A:G2...G2
To A:G2...G2(end of file)
File
Save
Escape
A:SMITH.WK3
Print
Printer
Range
Go

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